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# Physical and Chemical STUDIES OF SOILS In North Central Ohio Vineyards

## OHIO AGRICULTURAL EXPERIMENT STATION

Wooster, Ohio

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## COVER CROP

The cover crop of rye in the vineyard pictured on the cover will assist in maintaining better tilth and organic matter content of the soil and will help to control erosion.

# PHYSICAL AND CHEMICAL STUDIES OF SOILS IN NORTH CENTRAL OHIO VINEYARDS

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## INTRODUCTION

During the past 20 to 40 years, grape growers have reported a considerable decline in the yield of grapes on the islands and along the lake shore of north central Ohio. As an example, in the 1890's there were 916 acres in bearing on Kelley's Island, with an average yield of 3 tons per acre. The present acreage on Kelley's Island is about 150, with an average yield of 1 ton per acre or less. These figures are for the Catawba variety.

This decline in both yield and acreage cannot be entirely attributed to economic conditions or to the increasingly difficult problem of control over insect pests and diseases. Many vineyards are quite old, some being as much as 90 years of age. Others are not as old from the standpoint of the age of the vines, but they are on locations which had previously been in vineyards for many years. This means that a large number of vineyards are on sites where the soil has been subjected to the usual vineyard cultural treatments for a long period of time. In other words, the present vines are not growing under the same kind of soil conditions as did the original vines.

It is the purpose of this study to attempt to determine in what fundamental way the surface soil stability, as revealed by aggregation, and the fertility or chemical constitution of the soil has altered in some representative commercial vineyards in north central Ohio.

## LITERATURE REVIEW

It would be impractical to review or discuss, even in a brief fashion, all the work that has been done on changes in soil stability or in chemical composition that occur under different cultural practices. Only a few papers will be mentioned which are concerned with a similar type of study on field crop or orchard soils.

In 1909, Alway (2) noted a loss of nitrogen, total organic matter, and humus when he was studying the changes caused by cultivation in the composition of the loess soils of Nebraska. Stephenson and Schuster (12) found that cultivated orchard soil in western Oregon contained from one-fifth to two-thirds less organic matter than similar uncultivated soil. They also found an appreciable change in surface soil stability associated with tillage and organic matter depletion. Tillage pans that interfered with water penetration were formed and the soil surface was dispersed and run together until water could not penetrate.

In a bulletin on orchard soil management, Shaulis and Merkle (11) state that clean cultivation leads to soil depletion, which manifests itself in the form of decreased organic matter and nitrogen as well as diminished permeability.

In a comparative study of cropped and virgin soils, Dorman (6) found nitrogen to be the only element that showed a significant loss.

Brown, Wyatt, and Newton (4), in reporting the effects of cultivation and cropping on the chemical composition of some Western Canada prairie soils, showed nitrogen losses for the surface 6 inches varied from 96 to 7000 pounds per acre. Organic matter losses ranged from 1 to 90 tons per acre when compared to the original amount present. Also, significant losses of water-soluble phosphorus were noted in a number of cases. They concluded that one-fifth to one-third of the organic matter of the soil was lost over a period of 30 years.

Havis (7), through his study of the aggregation of soil under different cultural treatments, showed that the state of aggregation was in fairly close relation to the per cent of soil organic matter, except for the high aggregate formation under a wheat straw mulch. Other investigators, among them Browning and Milam (5), are working on methods whereby soil aggregation or physical condition can be improved, or at least maintained at nearly optimum levels.

## LOCATION AND METHOD OF SAMPLING

Soil samples were obtained during July 1943 from Middle Bass Island, the Sandusky region, near Berlin Heights, the Vermillion region, and the Avon Lake section east of Lorain. Twelve locations, together with the derivation of the soil in each area, are designated as sample numbers on the accompanying map (fig. 1).

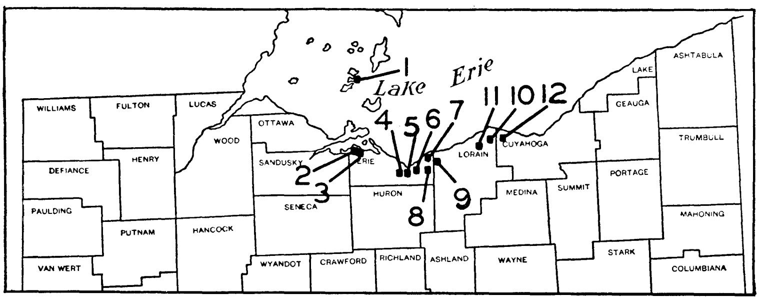


**Fig. 1.—Location of vineyard soil samples obtained for physical and chemical determination. Origin of the soil in these samples is: 1 to 3, glacial till over limestone; 4 to 6, sand and gravel beach ridges; 7 to 9, glacial silt and clay over shale and sandstone or siltstone; 10, sandy beach ridge; 11, silt and clay south of beach ridge; and 12, silt and clay north of beach ridge.**

In most cases, an attempt was made to obtain as old a vineyard site as possible within the locality. Because of erosion, a sample of the A horizon could not always be obtained, so a composite sample of the surface soil to a depth of 8 inches was taken from each vineyard selected, along with a composite sample of similar depth from a nearby fencerow or wood lot which appeared to have been undisturbed for a number of years. In this way, the soil samples obtained from a particular locality were similar with respect to soil type and origin but differed principally because of the effects of cultural practices. It is possible that the fencerow or wood lot soils are not exactly similar to the original soils on which the vineyards were planted, because minor changes could have been brought about through erosion, grazing, or from other causes. However, such samples represent the best check obtainable in this respect.

## SAMPLE PREPARATION AND METHODS OF ANALYSIS

All soil samples were air dried, screened through a 5-mm. screen, thoroughly mixed, and then stored in cans with tight fitting lids. Aggregate analyses were carried out according to the Yoder (16) wet-screen method. Analyses, using 50-gram samples of the prepared soil, were made in triplicate and the averages calculated for presentation as results. The weights of the mechanical separates of each of the aggregate size classes were obtained following the procedure outlined by Olmstead et al. (8).

A part of each air-dried sample was crushed with a hard wood rolling pin and screened through a 2-mm. sieve for chemical analysis.

Total exchangeable bases were determined by leaching the soil with a neutral normal ammonium acetate solution, as described by Bray and Wilhite (3), and Schollenberger and Dreibelbis (10). The solutions remaining from the exchangeable base determinations were made to volume and aliquots taken for calcium and potassium determinations.

Calcium was determined according to the micro method described in the Fifth Edition of the Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists (1) and potassium, by the method outlined by Wander (15).

Readily available phosphorus was determined by the method of Truog (14) and total nitrogen by the official method (1).

Portions of the air-dried and screened samples were ground in a ball mill to pass a 100-mesh screen and organic matter was determined by the Tiurin (13) modification of the original Schollenberger method (9). The glass electrode was used for pH determinations.

## SOIL STABILITY AS REVEALED BY AGGREGATE ANALYSIS

For practical purposes, soil stability may be defined as the ability of a soil to retain its granular character when wet (will not run together and become puddled). A measure of the water-stable aggregates in the surface of a soil is therefore really an indirect measure of the capacity of a soil for aeration and water penetration. A necessity for good plant growth is that the surface soil retain its granular character when wet and not run together and become impervious to water and air penetration, so as to limit the air and moisture relationships of the entire profile.

Five class sizes of aggregates were separated out as they existed in the samples. These classes consisted of particles 2 mm. in diameter or above, 2 to 1, 1 to 0.5, 0.5 to 0.25, and from .25 to .1 mm. in diameter. The appearance of the five class sizes of aggregates is shown in figure 2. These results, along with the mechanical separates of each size class, were plotted as per cent of the total sample against the various size classes beginning with those above 2 mm. Typical curves obtained by this means are shown in figures 3, 4, and 5.

Results were also calculated to give a single-valued figure, the pulverization modulus (17).

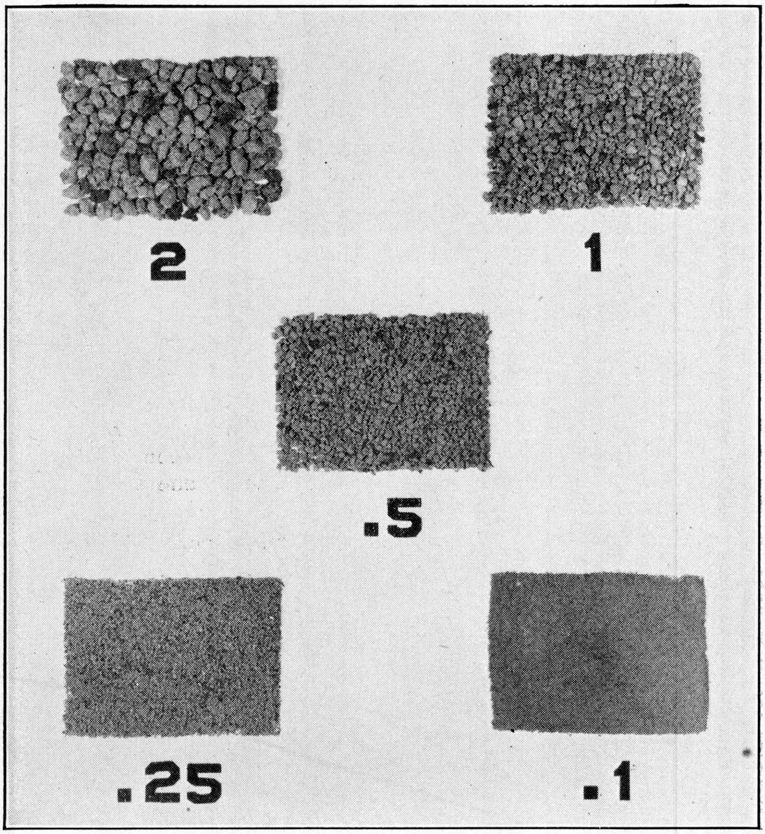


Fig. 2.—Appearance of the five class sizes of aggregate separations made. The number under each class is the size of that separation in millimeters.

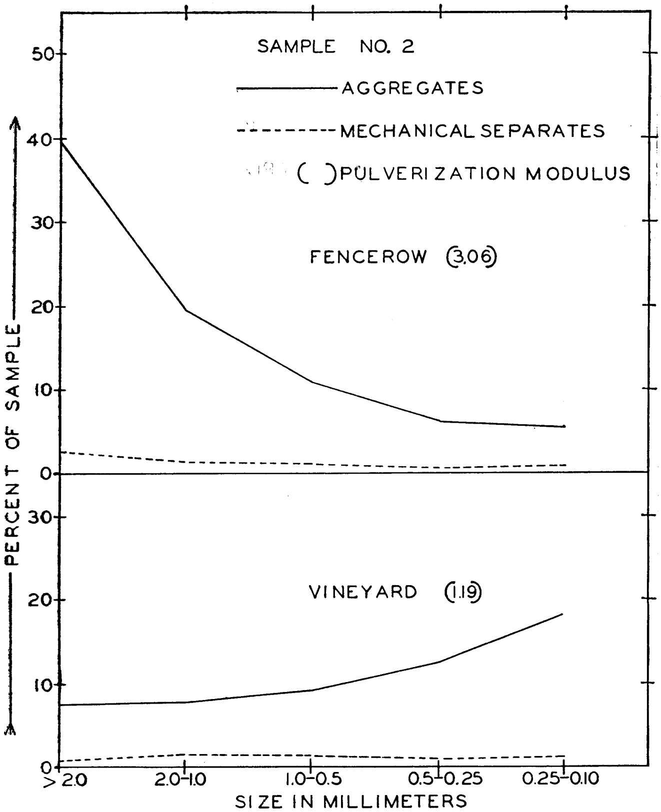


**Fig. 3.—Aggregation and mechanical analysis of a vineyard and adjacent fencerow near Sandusky, Ohio. Sample number refers to location on the map in figure 1.**

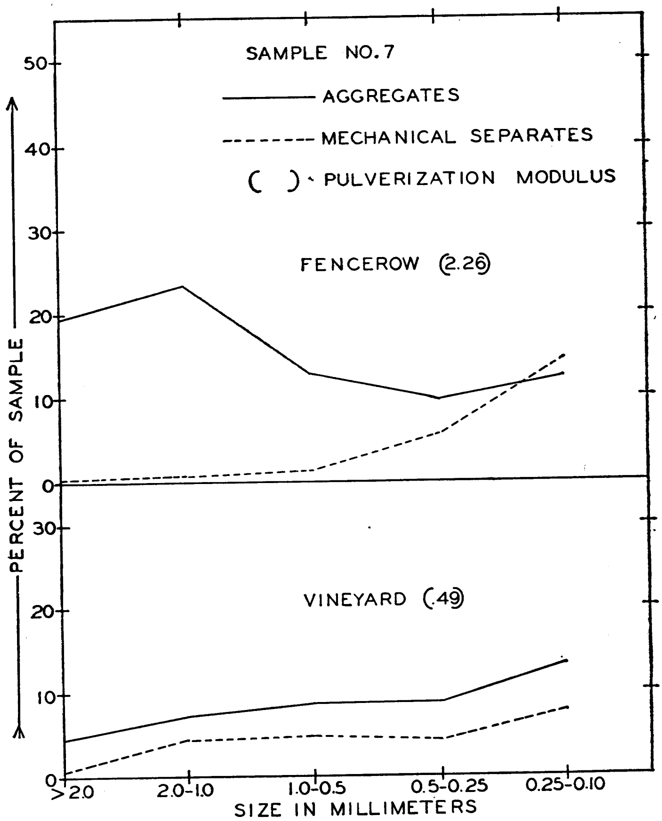


**Fig. 4.—Aggregation and mechanical analysis of a vineyard and adjacent fencerow near Vermillion, Ohio. Sample number refers to location on the map in figure 1.**

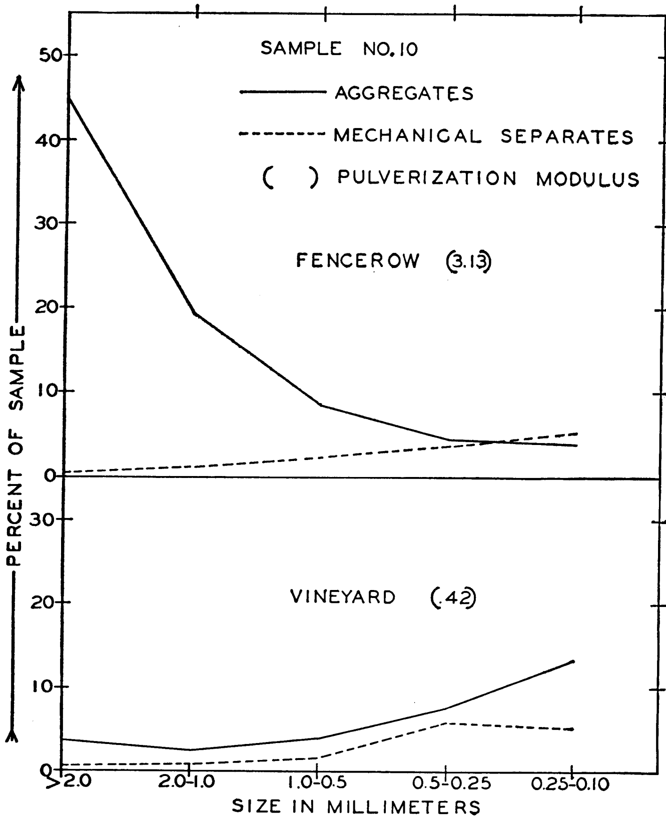


**Fig. 5.—Aggregation and mechanical analysis of a vineyard and adjacent fencerow near Lorain, Ohio. Sample number refers to location on the map in figure 1.**

**TABLE 1.—Pulverization moduli (degree of soil pulverization) for 12 north central Ohio vineyards and their respective undisturbed comparison samples**

| Sample number | Pulverization modulus | |
|---|---|---|
| | Vineyard | Adjacent fencerow or wood lot |
| 1 | 0.24 | 2.00 |
| 2 | 1.19 | 3.06 |
| 3 | 1.46 | 3.06 |
| 4 | .26 | 1.55 |
| 5 | .37 | 1.36 |
| 6 | .32 | 1.52 |
| 7 | .49 | 2.26 |
| 8 | .31 | 1.73 |
| 9 | .79 | 2.74 |
| 10 | .42 | 3.13 |
| 11 | 2.24 | 3.24 |
| 12 | 1.42 | 2.73 |

The pulverization modulus, hereafter referred to as P. M., is the sum of the cumulative percentages of particles of greater diameter than the successive openings in a graded nest of screens, beginning with the largest, divided by 100. Therefore the larger the P. M., the greater the proportion of aggregates in the larger class sizes, and, conversely, the smaller the P. M., the smaller the proportion of aggregates in the larger class sizes. The P. M. for each of the 24 soil samples is given in table 1. In all vineyards studied the aggregation, or stability of surface soil granules, has been considerably decreased as compared to nearby undisturbed soil.

These results indicate that most of the grape growers of this region are raising grapes on soil sites which have markedly declined in physical characteristics. This resultant poor aggregation has been brought about by years of tillage. Originally, thorough and frequent tillage was the best cultural practice because it effected a rapid release of nutrients by the oxidation of accumulated organic matter in the virgin soil. At present, however, excessive tillage simply continues and accentuates the undesirable physical character of the soil which has developed during long periods of tillage. Thorough tillage can no longer release nutrients to the growing vines because very little organic matter remains in the soils of many of these vineyards. (Fig. 6).

## RESULTS OF CHEMICAL ANALYSES

### Organic Matter

In all of the vineyard soils studied, except one, the organic matter is considerably lower than the adjacent check samples, figure 6. The reduction in organic matter varies from 20 to 80 per cent of what may be presumed to have been originally present. This decline in organic matter content of the soil has resulted from high rates of oxidation brought about by excessive tillage, failure to replenish organic matter by the use of cover crops or manure, and loss of most of the top soil by erosion, in many cases a very serious factor.

### Total Nitrogen

Total nitrogen losses in the vineyard soils very closely parallel the organic matter losses (fig. 7). One vineyard soil retained only 15 per cent of the total nitrogen which was originally present as indicated by the adjacent check sample. Undoubtedly, this loss of total nitrogen is a limiting factor in the production of this particular vineyard.

### Total Exchangeable Bases

The total exchangeable bases are lower in all the vineyard soils studied in this series than the adjacent fence-row or wood-lot samples. Thus, the vineyard soils contain only from 18 to 76 per cent of the original amount which may be assumed to have been present (fig. 8). The difference between the amount of exchangeable bases in vineyards on different soil types is quite large. This difference is due largely to the greater amounts of exchange calcium in the soils from the limestone region. (nos. 1, 2, and 3, in fig. 8).

### Calcium

The exchange calcium followed the pattern of the total exchangeable bases; that is, it was considerably lower in most vineyards than in the adjacent untilled land. In only 2 of the 12 vineyards studied was the exchange calcium equal to that of the nearby fencerow or wood lot soil (fig. 9). In one vineyard located on soil underlaid with limestone (no. 1, fig. 9) in which the exchange calcium would normally be high, the exchange calcium is actually lower than in other vineyards underlaid with shale and sandstone (nos. 7, 10, 11, in fig. 9), where exchange calcium would be expected to be low. This indicates that excessive tillage has aided erosion and leaching processes to deplete the calcium content of a soil that would normally have a high calcium content.

### Potassium

Six of the vineyard soils studied contain more exchange potassium than their check samples (nos. 2, 3, 4, 5, 6, and 8, in fig. 10); whereas, the other six vineyard soils contain less than their respective check samples (nos. 1, 7, 9, 10, 11, and 12, in fig. 10). No potassium fertilizer was known to have been used in any of the vineyards studied. Cultivation apparently had no consistent effect on this element. It was noted, however, that the exchange potassium varied considerably in different locations, thus indicating, as might be expected, that soils of different origin vary widely in this respect.

### Phosphorus

The readily available phosphorus in the vineyards has not declined from that in the nearby fencerows or wood lots, except where there has been severe erosion and loss of organic matter (nos. 1 and 7, in fig. 11). In most cases the readily available phosphorus in vineyard soils is equal to, or higher, than that in adjacent fencerows or wood lots. Like calcium, the readily available phosphorus is much higher in those soils of limestone origin than in soils derived from sandstone and shale.

### Soil Reaction

A comparison of these vineyard soils with adjacent undisturbed samples shows that the pH of the heavier vineyard soils has decreased slightly; whereas there has been a slight increase in vineyards located on sandy soils.

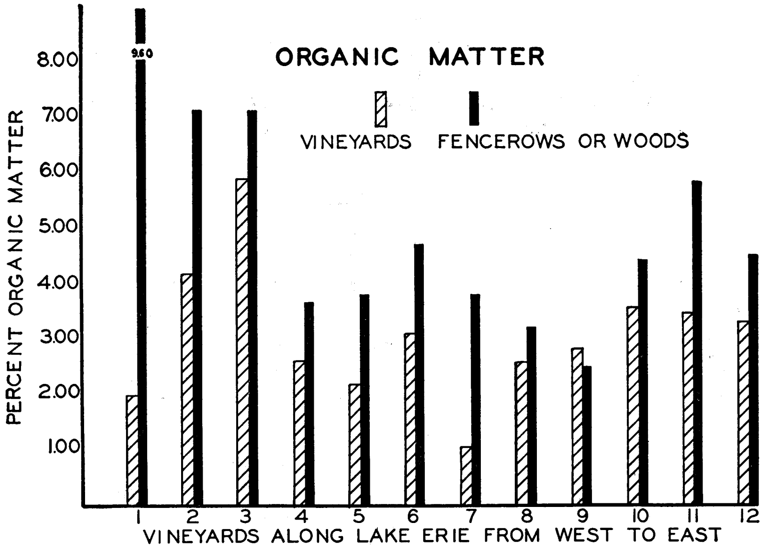


**Fig. 6.—Per cent organic matter in 12 north central Ohio vineyards compared to adjacent undisturbed soil samples. Numbers on the abscissa refer to the sample locations on the map in figure 1.**

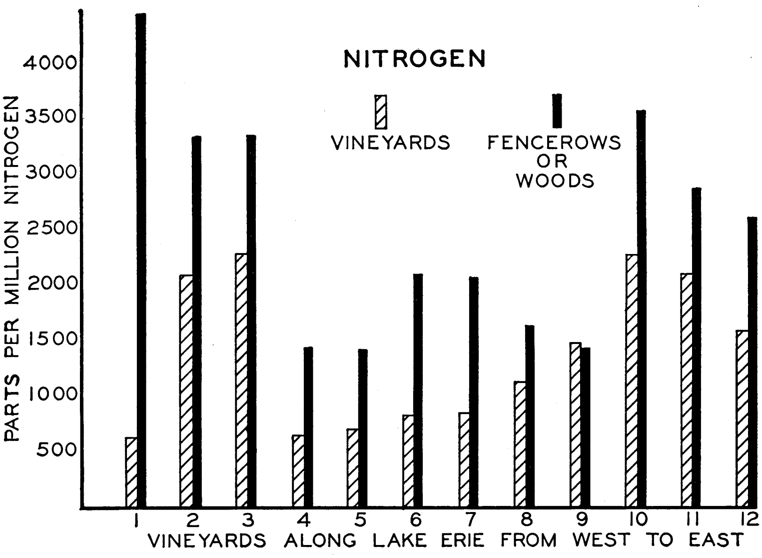


**Fig. 7.—Total nitrogen in 12 north central Ohio vineyards compared to adjacent undisturbed soil samples. Numbers on the abscissa refer to the sample locations on the map in figure 1.**

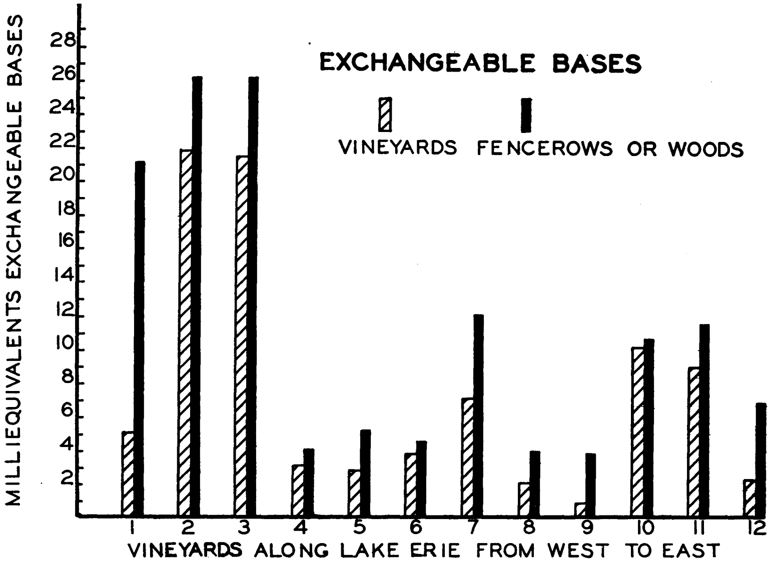


**Fig. 8.—Milliequivalents exchangeable bases in 12 north central Ohio vineyards campared to adjacent undisturbed samples. Numbers on the abscissa refer to the sample locations on the map in figure 1.**

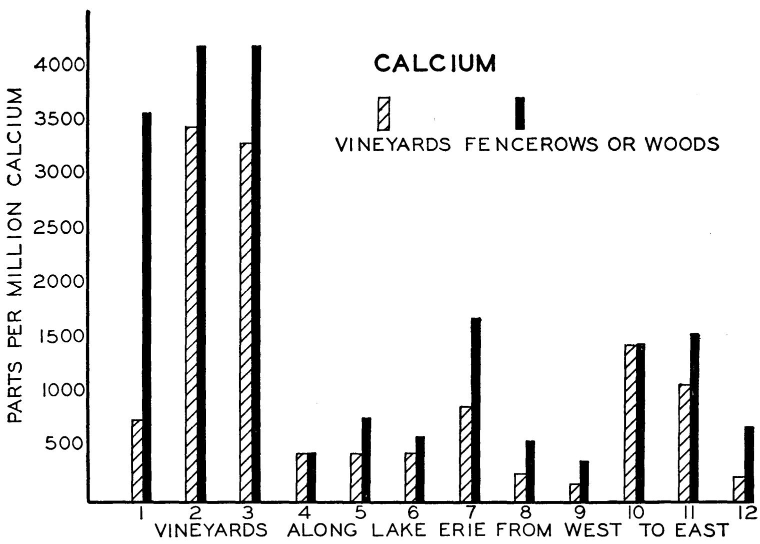


**Fig. 9.—Parts per million of exchangeable calcium in 12 north central Ohio vineyards compared to adjacent undisturbed soil samples. Numbers on the abscissa refer to the sample locations on the map in figure 1.**

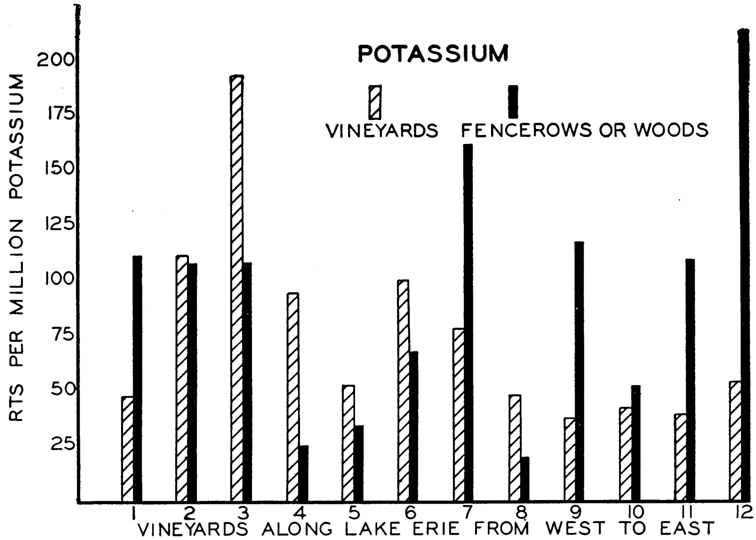


**Fig. 10.—Parts per million of exchangeable potassium in 12 north central Ohio vineyards compared to adjacent undisturbed soil samples. Numbers on the abscissa refer to the sample locations on the map in figure 1.**

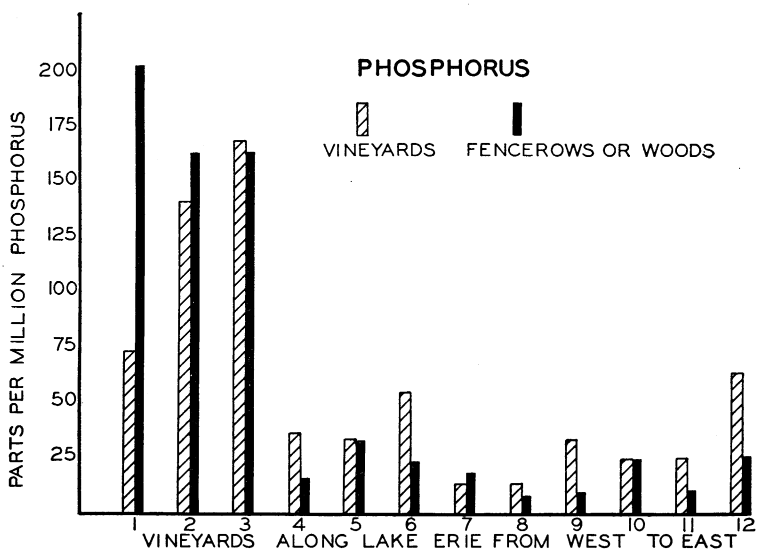


**Fig. 11.—Parts per million of readily available phosphorus in 12 north central Ohio vineyards compared to adjacent undisturbed soil samples. Numbers on the abscissa refer to the sample locations on the map in figure 1.**

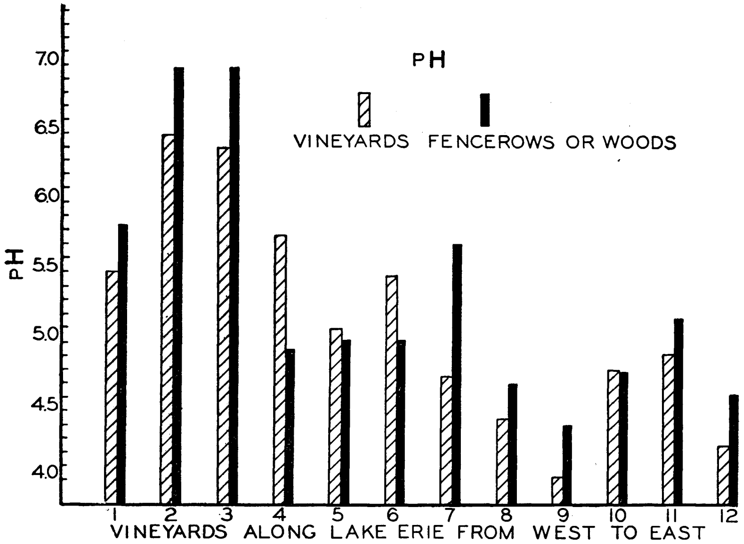


**Fig. 12.—Soil reaction in 12 north central Ohio vineyards compared to adjacent undisturbed soil samples. Numbers on the abscissa refer to the sample locations on the map in figure 1.**

This change in pH is correlated with the change noted in exchangeable calcium; that is, there is a greater decrease in exchange calcium on the heavier soils than on sandy soils. However, in none of the vineyard soils studied was there any indication that the soil reaction would be unsatisfactory for grape growing.

## GENERAL RECOMMENDATIONS AND CONCLUSIONS

The explanation for progressively lowered yields of all varieties of grapes in the Lake Region has not been clear. Several factors are undoubtedly involved. There are many old vineyards which no longer are profitable, although some of them still yield well in some seasons. It would seem better to renew vineyards, particularly on unfavorable soils, after 20 to 25 years. In other words, a plan for succession of vineyards should be followed, so that blocks of vines of different ages would be maintained.

Another source of difficulty is the continued cutting of roots by deep plowing or disking near the vines. A system of tillage which would avoid this damage is urgently needed and the use of some tool such as the Anderson grape hoe would be an improvement over equipment now used.

Unfavorable sites, especially where the soil has inadequate natural drainage or where frost damage is likely to occur, are to be avoided since no cultural, fertilizer, or spray program will overcome such handicaps. On rolling or hill land the contour system of planting is desirable and is finding a place in Ohio viticulture.

Investigations have shown that many soils with poor aggregation do not respond to fertilizer treatments even though they are low in nutrient elements.

Even though nutrients are present in sufficient concentration, they may not be utilized by plants unless there is sufficient aeration and drainage or water penetration and holding capacity.

Some long continued tests with various fertilizers in two locations in the area under consideration have shown that grapes growing on depleted or eroded soils gave no response to commercial fertilizers of any kind or analysis used. On more favorable soils, the chief element to give response was nitrogen used at the rate of 250 pounds of ammonium sulfate per acre (or its equivalent in some other carrier). On the poorer soils, grapes responded rather strikingly to applications of stable manure at the rate of 8 to 10 tons per acre.

A complete fertilizer, such as a 10-6-4, used at the rate of 500 pounds per acre may be used to secure increased growth of cover crops. An application of agricultural lime may be required in some cases. A cover crop of oats or rye sown during late summer at the rate of 2 bushels per acre (or buckwheat at the rate of 1 bushel per acre) is recommended to assist in maintaining a better tilth and organic matter content of the soil and to help control erosion.

Finally, the main findings of this bulletin point out the destruction of a favorable surface soil aggregation and a serious loss of organic matter and total nitrogen by long continued, intensive tillage practices. A minimum of tillage consistent with optimum growth of vines, and the use of moderate applications of manure or fertilizer, with cover crops, would go far toward remedying the serious soil and cultural situation found in this area.

## SUMMARY

The most outstanding facts revealed by this study are that:

1. A favorable surface soil granulation or good state of aggregation has been destroyed in many north central Ohio vineyards by excessive cultivation and the lack of cover crops or manure over a long period of time.

2. Organic matter and total nitrogen, which are very closely related to aggregation, have been seriously depleted in many vineyards. Organic matter losses varied from 20 to 80 per cent, whereas losses of total nitrogen as high as 85 per cent were recorded.

3. The decrease in total exchangeable bases ranged from 18 to 76 per cent of the original amount assumed to have been present.

4. Losses of the individual fertility elements calcium, potassium, and phosphorus are not as pronounced as the loss of organic matter and nitrogen but, in some cases, may become limiting factors, especially if sufficient organic matter and nitrogen are restored to the soil.

5. Only 2 vineyard soils out of 12 did not show a loss of exchange calcium. The amount of exchange calcium depends largely on the soil origin.

6. There is no consistent change, under the usual vineyard culture, of exchange potassium. Some soils originally contained more than others.

7. Except where there has been serious erosion and loss of organic matter, readily available phosphorus is equal to or higher in the vineyard than in adjacent undisturbed soil.

8. There has been no great change in soil reaction.

9. Less intensive cultivation and the use of manure or fertilizer with cover crops are recommended to restore and maintain soils in a more productive condition when they are to be used for growing grapes.

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